

ARTIFICIAL DIELECTRICS FOR ULTRA-WIDEBAND APPLICATION

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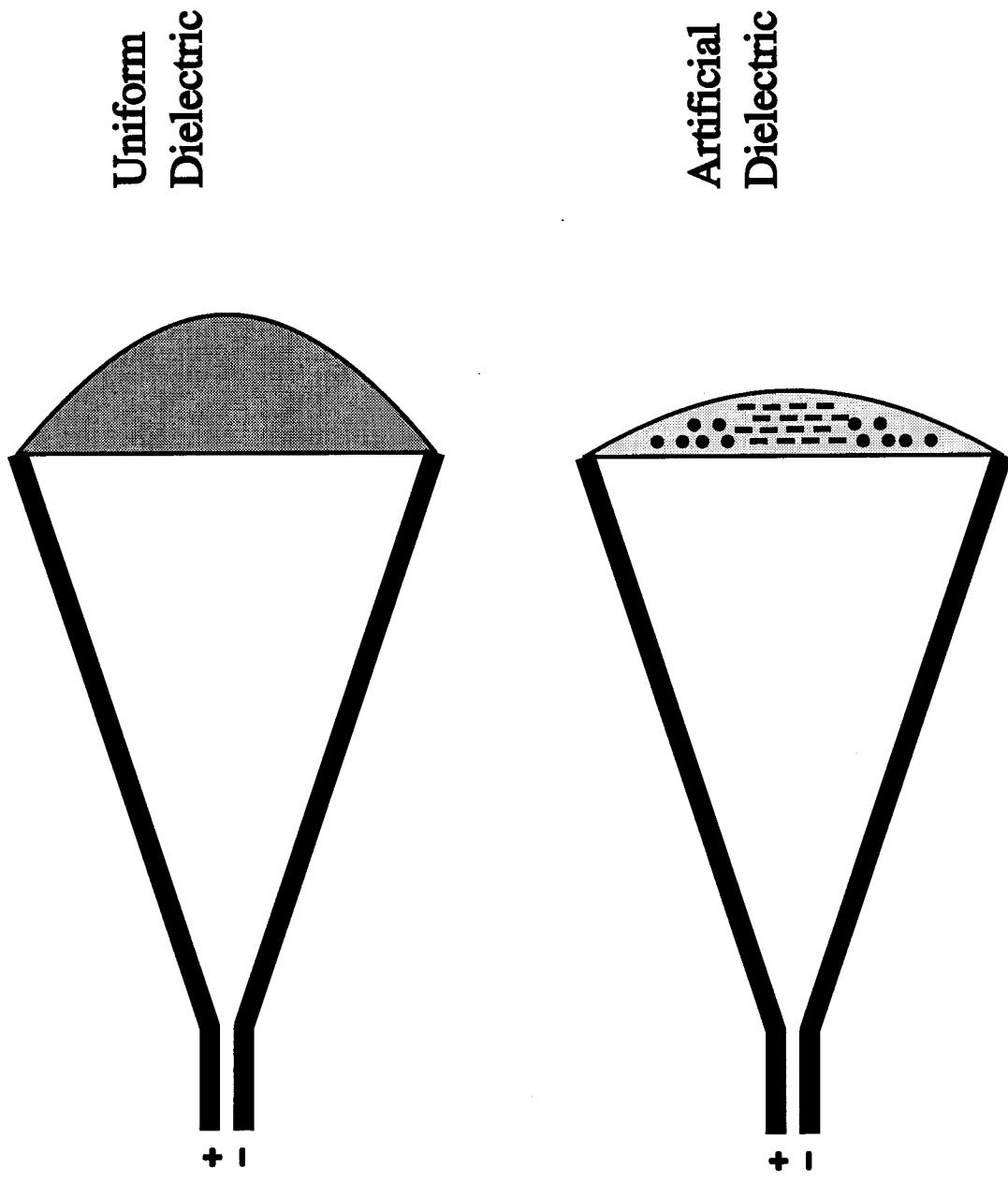
OVERVIEW

- RESEARCH OBJECTIVES
- HYBRID FINITE ELEMENT METHOD (HFEM)
- PRELIMINARY SIMULATIONS
- FUTURE DIRECTIONS

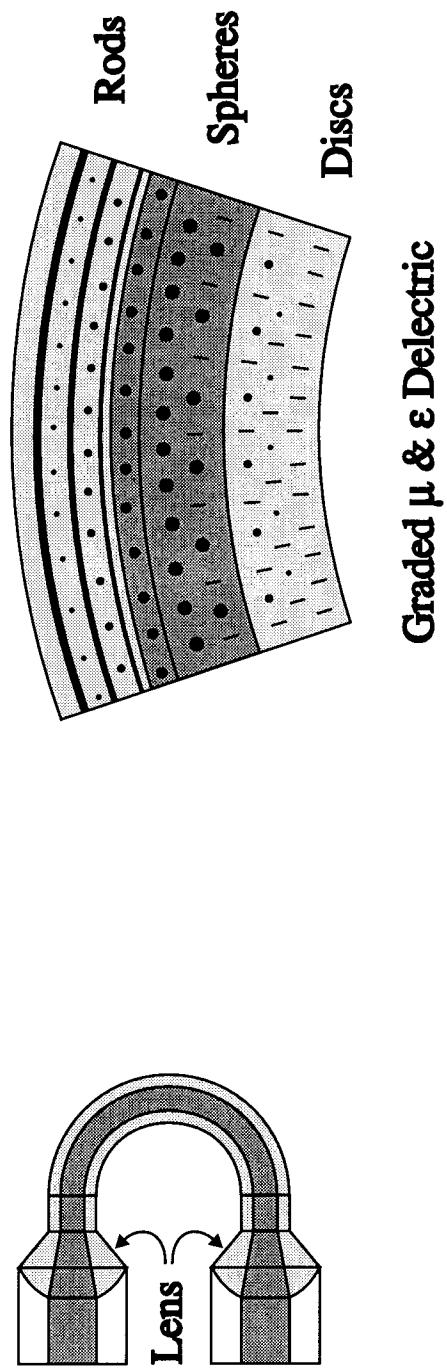
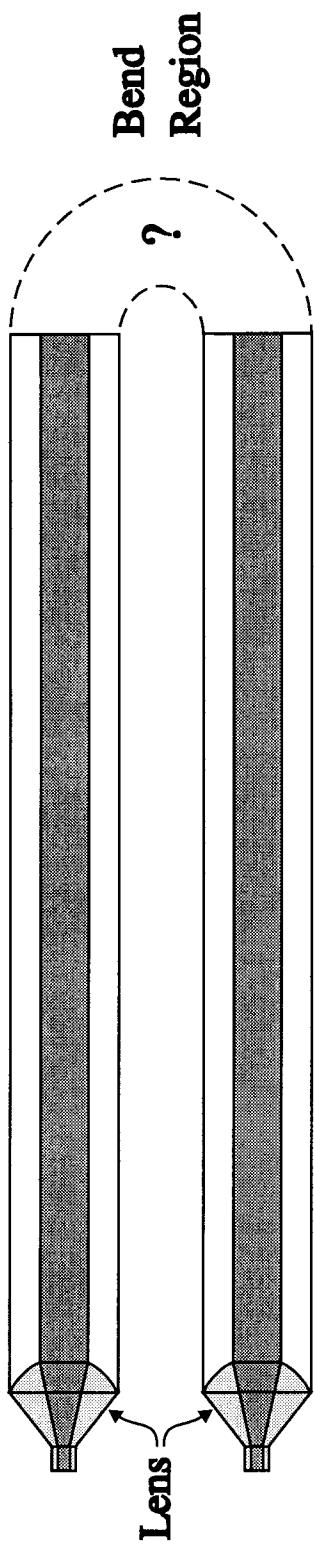
RESEARCH OBJECTIVES

- Develop Design and Analysis Methodology for Artificial Dielectrics
- Compare HFEM Simulations to Analytic/Empirical Expressions
- Desired Outcomes for Artificial Dielectrics
 - Lightweight, variable (graded) index Dielectrics
 - Low Loss
 - Low Dispersion
 - Minimize Static Field Enhancement
- Applications

Application to Lensed TEM Horn Antenna



Low-Loss Delay Line

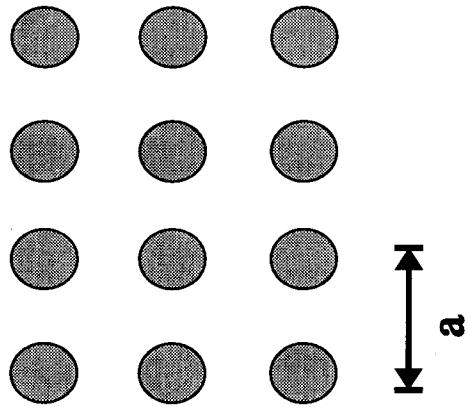


Graded μ & ϵ Dielectric

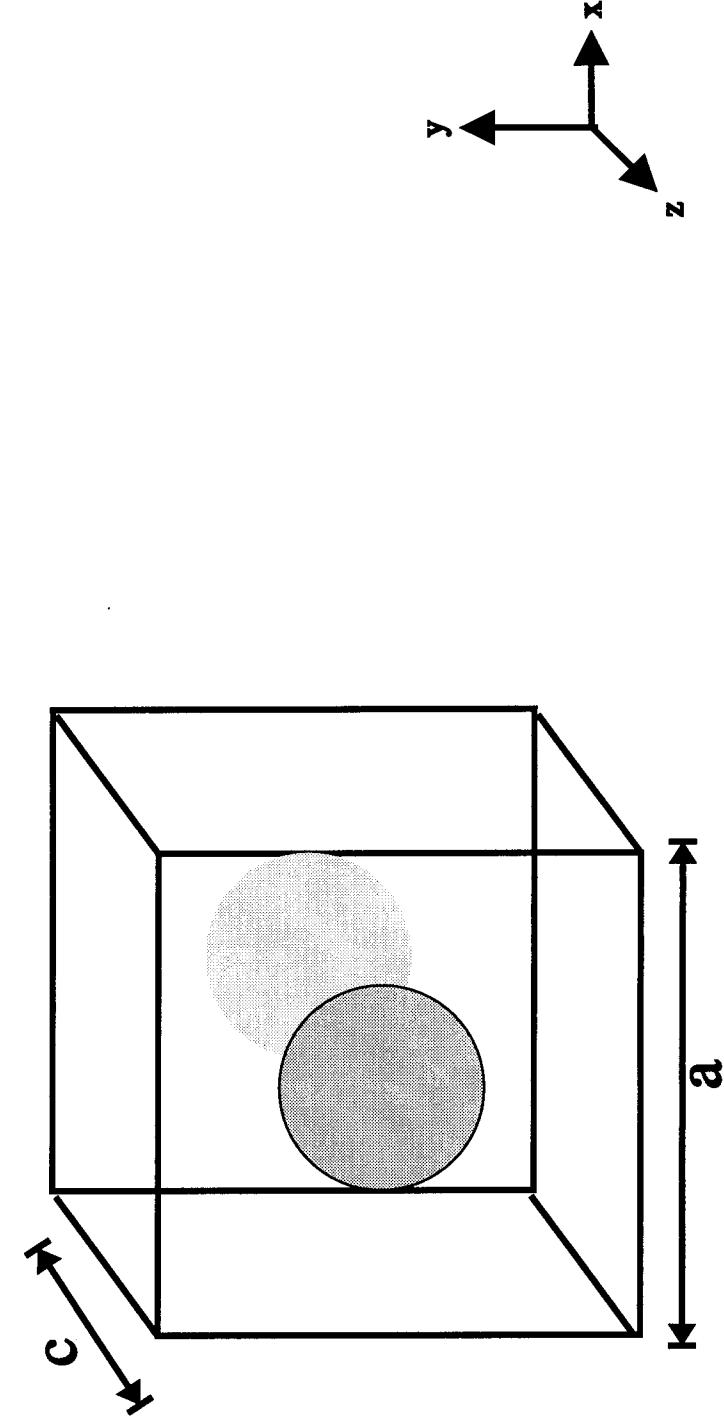
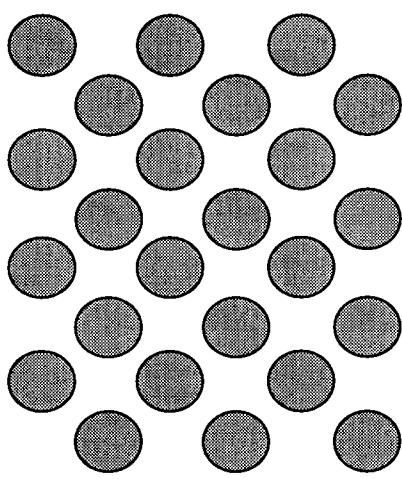
Bend Regions

Unit Cell Model for HFEM

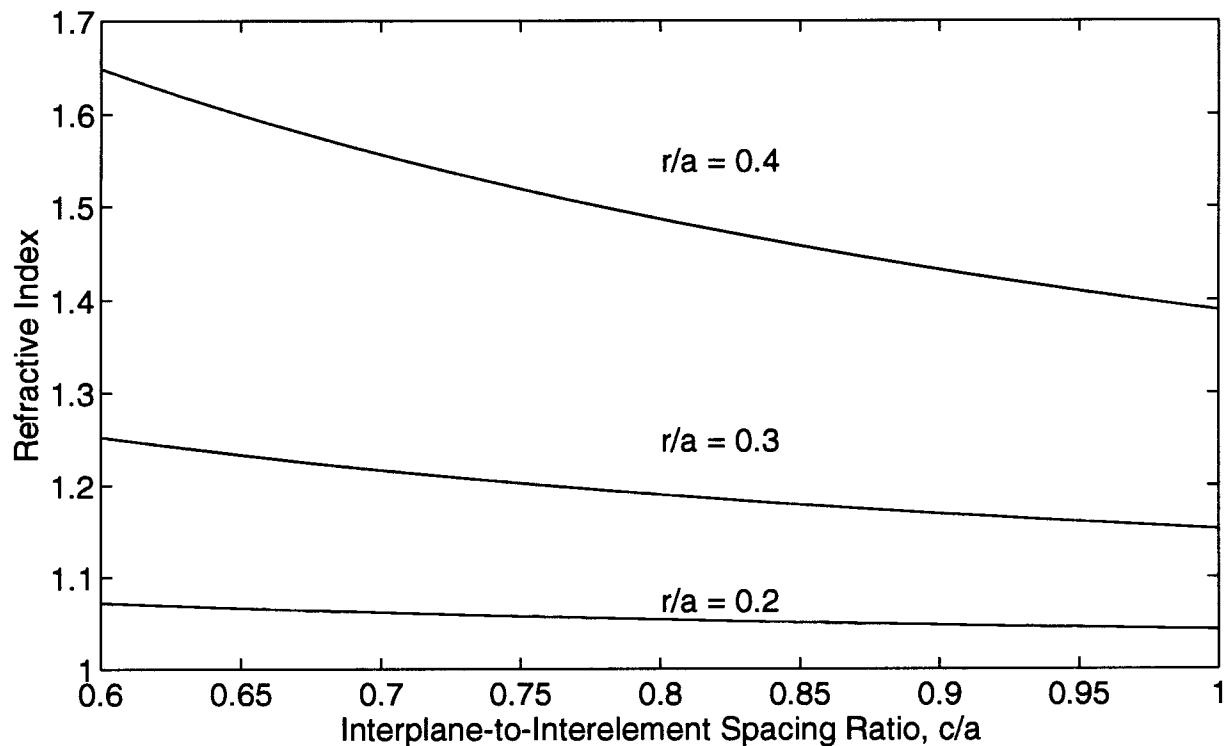
Rectangular Lattice



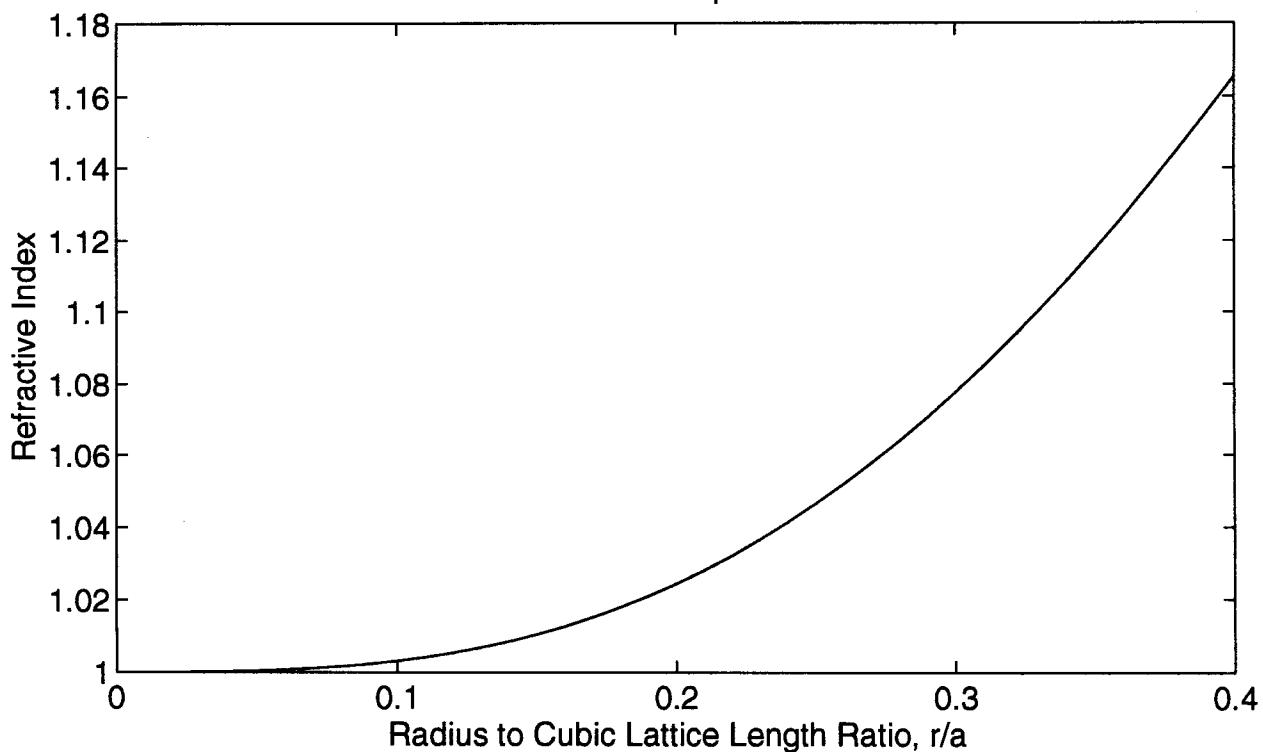
Triangular Lattice



Refractive Index for Thin Disks of Various r/a



Relative Index for Metallic Spheres in Cubic Lattice



HYBRID FINITE ELEMENT METHOD

- Full Wave Frequency Domain Analysis
- Unit Cell Concept
 - Infinite Periodic Array of Objects in Two-Dimensions
 - Propagation Dimension Finite
- Unit Cell divided into Mesh of Nodes and Finite Elements
 - Nominal Element Length: 2.5 mm ($0.0833\lambda_o$ at 10 GHz)
- Solves for Reflection and Transmission Coefficients
- Calculates Fields Throughout Unit Cell

HFEM

- The solution is implemented by constructing and solving:

$$[R] [S^{\Gamma-} + S^I + S^{\Gamma+}] [R]^H E = E^{inc}$$

where

- S^I is interior FE solution
 - $S^{\Gamma-}$ and $S^{\Gamma+}$ are FE due to radiation condition periodicity
 - R implements side wall periodicity
 - E^{inc} is unit amp plane wave
-
- Solve system for E

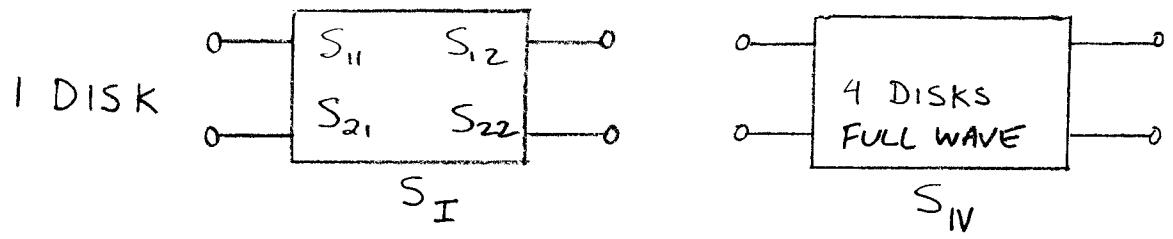
PRELIMINARY SIMULATION CONDITIONS

- Unit Cell: Square (square lattice) or Skewed (Triangular Array)
- Obstacles: Thin Metallic Circular Disks
 - Radii $r = 10$ mm, 7.5 mm, and 5.0 mm
- Center-to Center Spacing: $a = 25.0$ mm ($0.833\lambda_o$ at 10 GHz)
- Inter-Planar Spacing: $c = 15$ mm ($0.50\lambda_o$ at 10 GHz)
- Two-Port Symmetrical Network:
 - S -parameters S_{11} and S_{21} calculated
- Normal Incidence, Vertical Polarisation

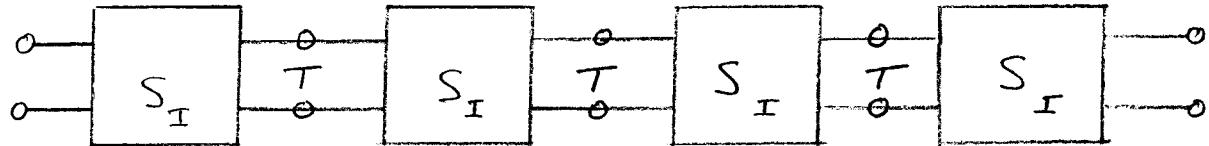
PRELIMINARY SIMULATIONS - CASE 1

Rectangular Lattice

- Disk radius $r = 10$ mm
- Effective Dielectric Constant $\frac{\epsilon_r}{\epsilon_b} = 2.2$
- Simulation Time for one plane of disks: 1.75 hours
- Simulation Time for four planes of disks: 7.0 hours
- Use Network Representation of single disk, then cascade N times
 - assumes dominance of TEM mode
 - excellent agreement with full-wave analysis

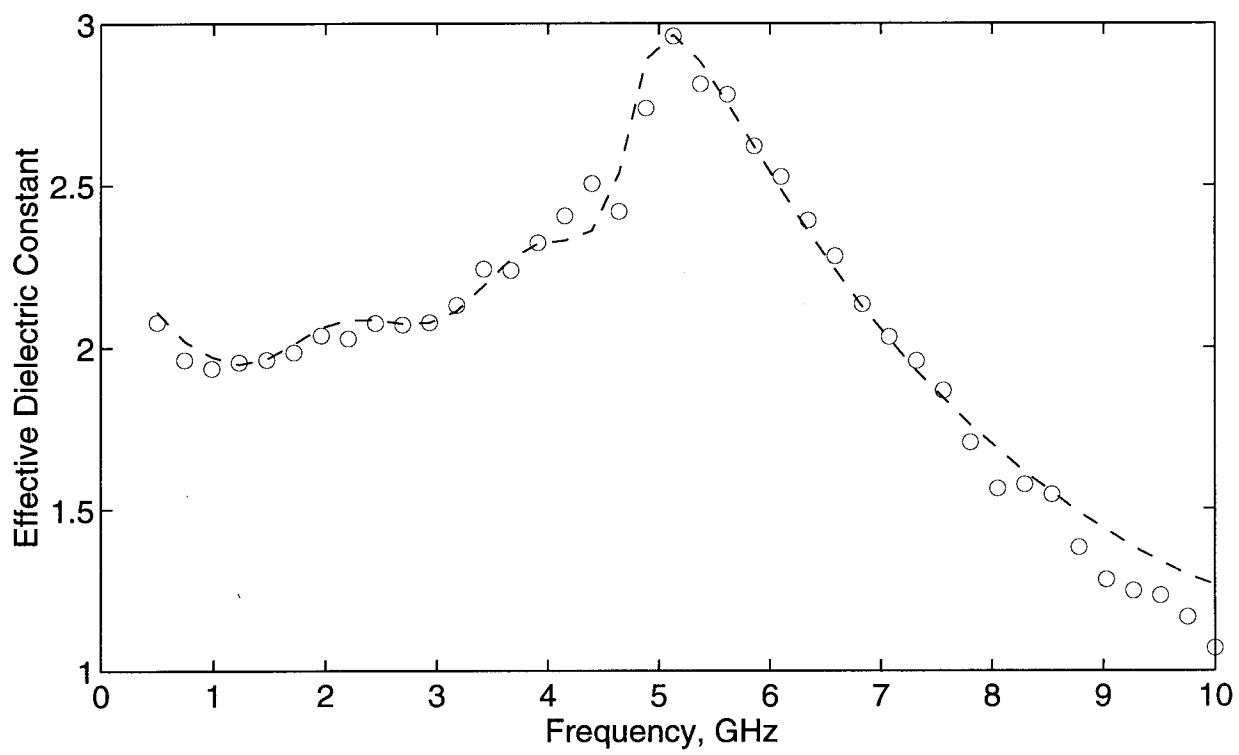
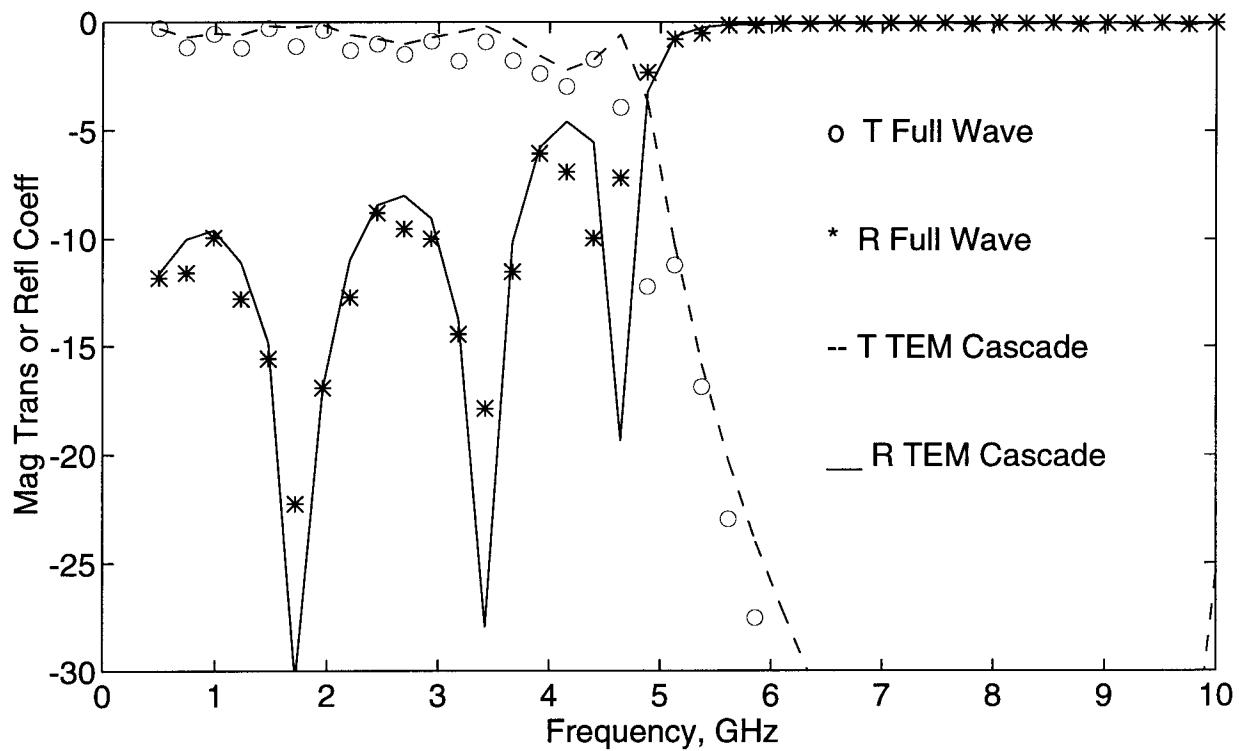


CASCADE



- However:

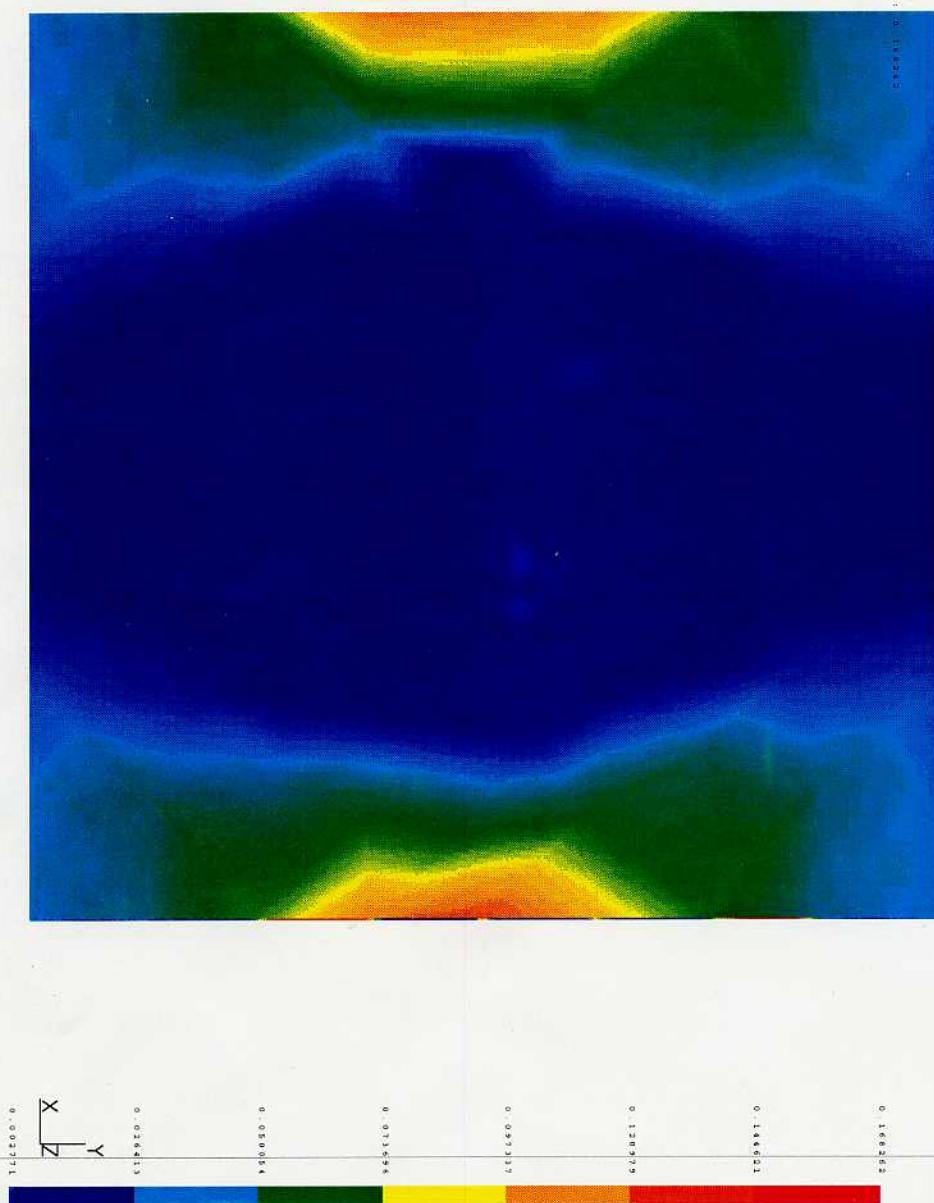
- Lattice has ‘low pass’ response
- Severe $\epsilon_{\text{eff}}(f)$
- Lattice has high field enhancement

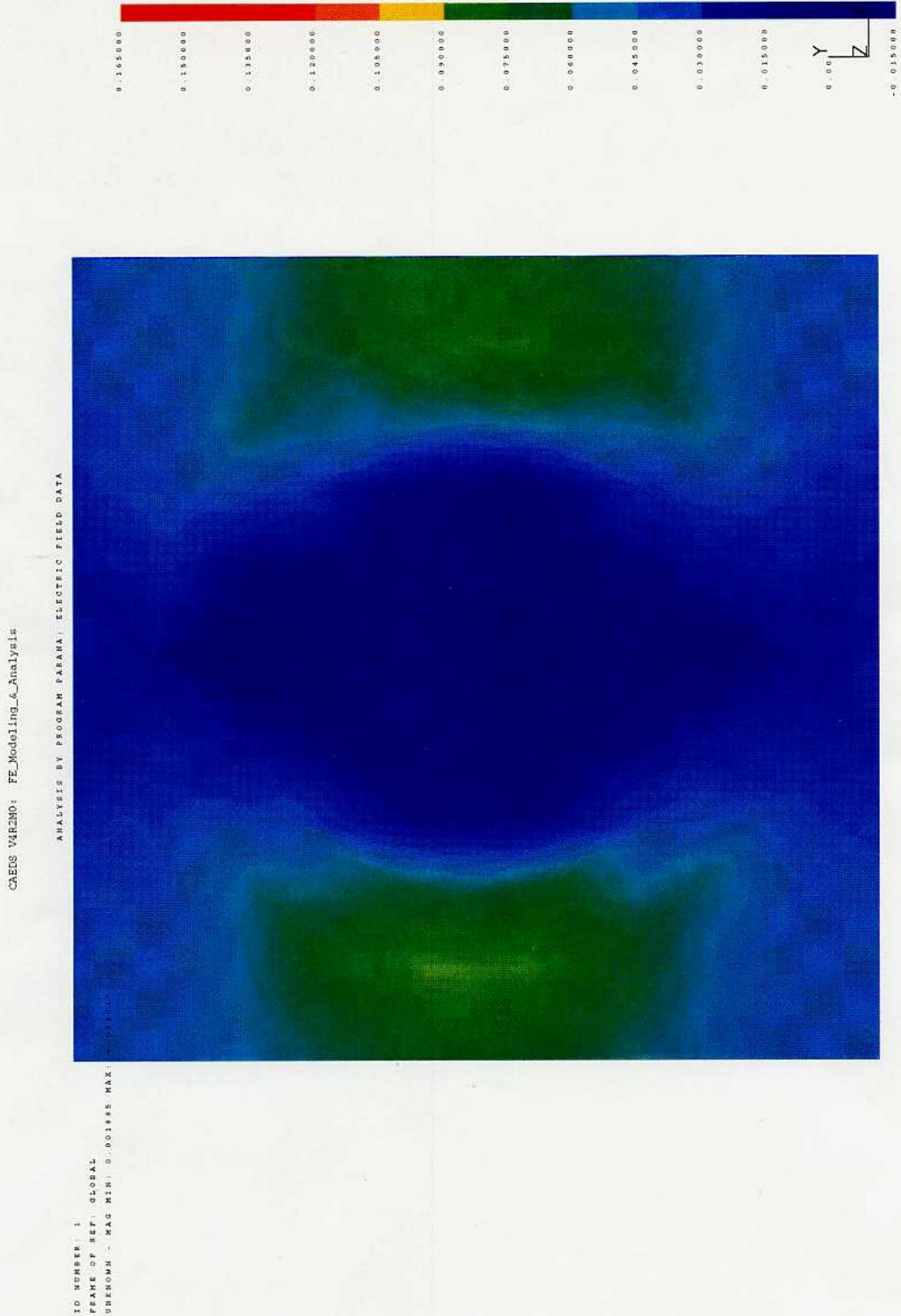


CARDS VARMD: FEModeling_Analysis

ANALYSIS BY PROGRAM PARAMA: ELECTRIC FIELD DATA

ID NUMBER: 1
PFMKE OF REFF: GLOBAL
UNKNOWN - MAG MIN: 0.00277 MAX: 0.16852

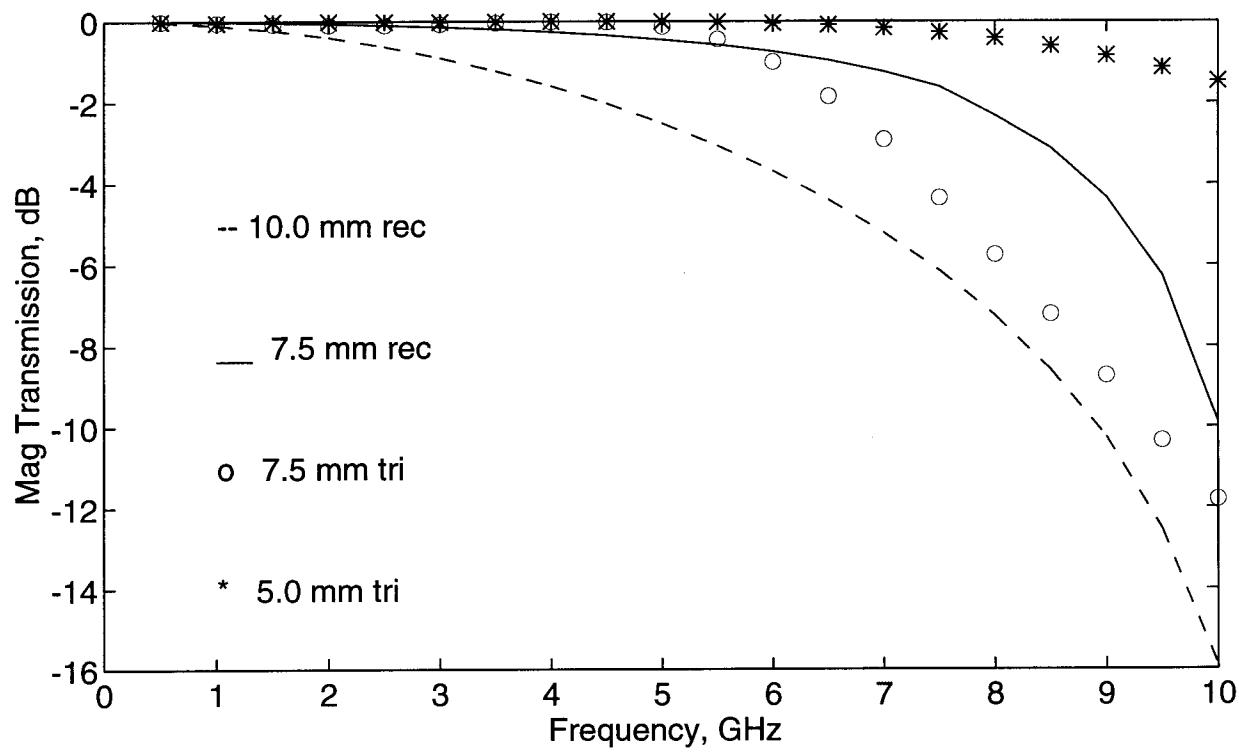
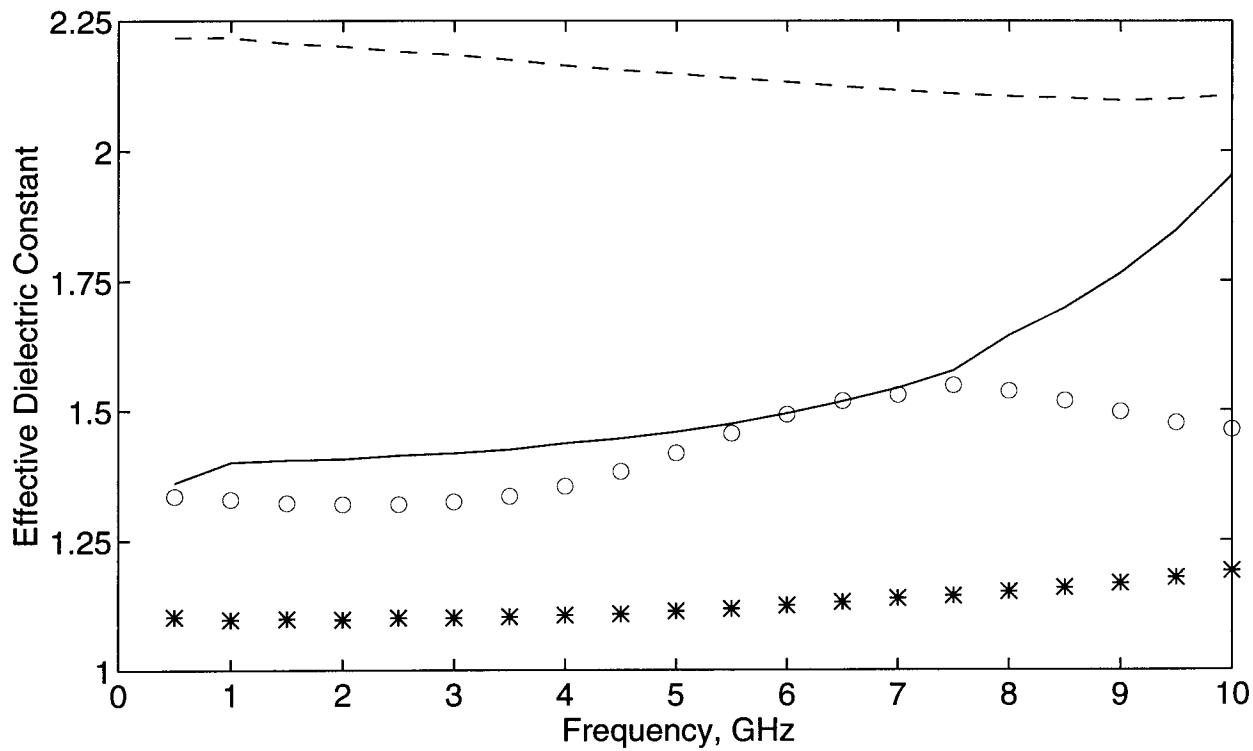




PRELIMINARY SIMULATIONS – CASE 2

Triangular Lattice

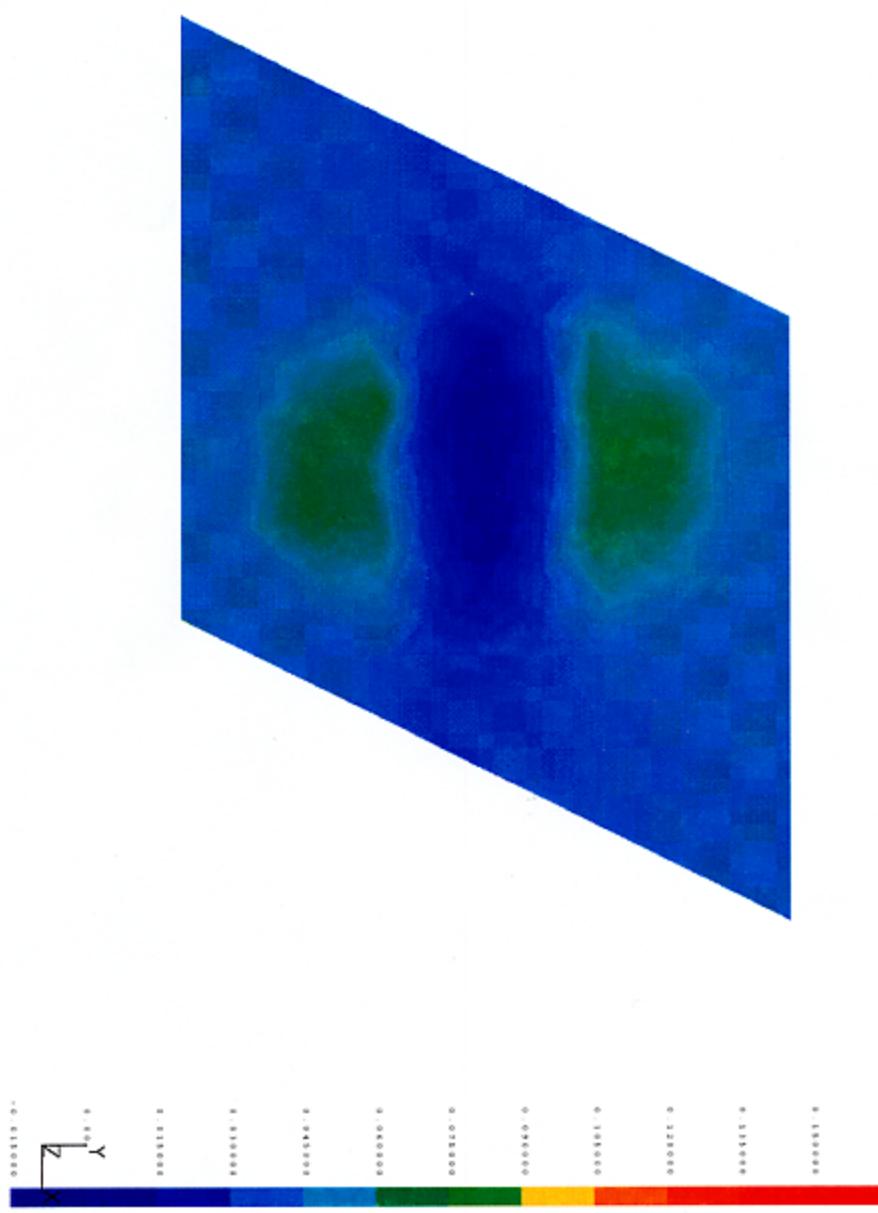
- Disk radii $r = 7.5$ mm and 5.0 mm
- Effective Dielectric Constants $\frac{\epsilon_r}{\epsilon_b} = 1.3$ and 1.1
- Excellent Phase Linearity over frequency
- ‘Low Pass’ response shifted to higher frequency
- Reduced Field Enhancement by over two times



CADS VIEW: FE_Modeling_Analysis

ANALYSIS BY PROGRAM PARAM: ELECTRIC FIELD DATA

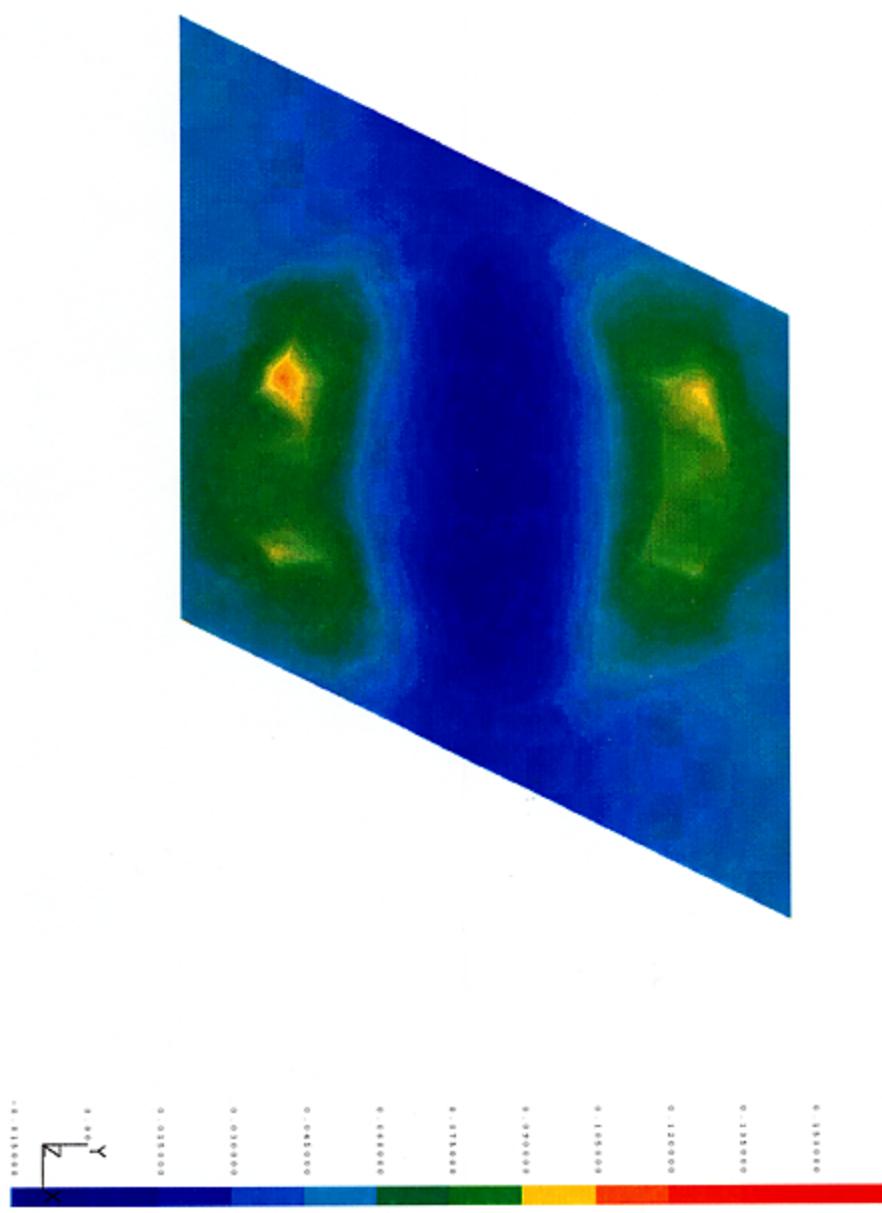
I.D. NUMBER: 1
FRAME OF REF: GLOBAL
THROW - MAGNITUDE COLOR MAP: 0.00001



CARDUS VARIABLE: FE_Modeling_Analysis

ANALYSIS BY PROFOUND PAPARA: ELECTRIC FIELD DATA

ID NUMBER: 1
FRAME OF REF.: GLOBAL
THROUGH - RAD. DIR.: 0.00000 MAX: 0.10000



FUTURE DIRECTIONS

- Simulate Effective Dielectric Constant of 'Interleaved' Triangular Lattice
- Simulate Impulse Response
- Build Promising Structures
- Evaluate Dielectric Constant, Impulse Response, and Field Breakdown Strength
- Apply to delay lines and UWB Antennas